Mitigating Vigilance Decrement: Evaluation of Technological Interventions.

A Masters Thesis Presented to

The Faculty of the Graduate School at

Cornell University

In Partial Fulfillment of

The Requirements for the Degree

Master of Science in Human Environment Relations

Concentration: Human Factors Ergonomics

By

Sagar Akre

August 2017

Abstract

Objective: The objective of this research was to investigate whether administration of various technological interventions during rest breaks would improve performance on post-break trials of an abbreviated vigilance task. **Background:** While previous studies have indicated the efficacy of rest breaks for restoring vigilance performance, few studies have been conducted on potential mitigate strategies. Attention Restoration Theory, which proposes that performance on sustained attention tasks may be restored in some part by interaction with nature, provides a useful framework for investigating potential mitigation strategies, access to nature is limited in many work environments. Therefore, the current study examines whether natural stimuli presented via 4k UHDTV's and virtual reality head mounted displays during short rest breaks would help to restore performance on subsequent tasks of an abbreviated vigilance task. **Method:** 45 Participants were asked to 2 trials of an abbreviated vigilance task (AVT) with a short 4-minute rest break in-between the two trials. During the rest break, participants experienced one of three of the following conditions: 1) control: standard rest break with no stimuli; 2) Virtual Reality: rest break in which participants viewed a natural scene using a HMD 3) Television: rest break in which participants viewed the same scene on a UHDTV. **Results:** While no significant differences were found between groups regarding reaction time, participants in the virtual reality condition had significantly higher accuracy on post-break trials of the AVT when compared to control and television conditions. **Conclusion:** Using virtual reality during rest breaks as a medium by which to mitigate vigilance decrement may prove to be useful in reducing errors in semi-automated human machine systems. **Application:** Findings from the current study may be applied to a variety of industries in which human operators are tasked with maintaining prolonged periods of vigilance in the lookout for critical signals.

BIOGRAPHICAL SKETCH

Sagar Akre is a 2nd year Master's candidate at Cornell University studying Human Factors and Ergonomics in the Department of Design and Environmental Analysis. He will be graduating in August of 2017. Dyring his time at Cornell, Sagar became interested in the ways in which design of various technologies may be used to enhance human cognitive and perceptual limitations.

Previously, Sagar attended the University of California at Riverside where he majored in Cognitive Psychology. While at UC Riverside, Sagar became involved with multiple research labs as a research assistant along with being the president of the boxing club for 2 years during his undergraduate career.

Currently, he has obtained an internship at a biotechnology firm named Proteus Digital Health in the Silicon Valley in California. At Proteus, he is working within the User Research Team as a Usability Research Intern.

Dedicated to everyone who has directly and indirectly played a part in my development as an individual

Acknowledgements

I would like to thank my parents, Anupama and Sunil Akre for their unconditional love and support during my time in school. I would not have been able to do it without knowing I can rely on both of you to be there for me. I would also like to thank my significant other, Ashley Herrera whose love and support were crucial to me being able to successfully complete my degree.

Furthermore, I would like to thank Dr. So-Yeon Yoon for advising me throughout this process. Working with Dr. Yoon has been one of the most rewarding and skill-building experiences I have ever had. Dr. Yoon has cultivated a supportive yet rigorous culture in her laboratory, which allows for graduate students who work with her to embark upon cutting-edge and exciting projects. Lastly, I would also like to thank Dr. Rana Zadeh who has provided me with support and insight into the various topics tackled in this thesis. Her great insight into the health-care field and feedback has allowed me to formulate a more coherent story for my research.

Table of Contents

INTRODUCTION

Vigilance decrement is a phenomenon by which one's ability to detect critical signals on a task which requires sustained attention is decreased as a function of one's time on the task (Finkbeiner, Russel, & Helton, 2016). Vigilance performance is crucial component to various job functions and is important in a variety of industries in which automated and semi-automated human-machine systems are used (Parasurman & Riley, 1997 as cited in: Warm, Parasurman & Matthews, 2008). In particular vigilance has been found to play a critical role in "cockpit monitoring, seaboard navigation, industrial process/quality control, long distance driving, agricultural inspection tasks…cytological screening, electrocardiogram monitoring, inspection of anesthersia gauges during survery…baggage inspection and detection of illicit radioactive materials.." (Warm et. al, 2008 pp. 434). While previous studies have shown the efficacy of rest-breaks at restoring performance on vigilance tasks, few studies have investigated other mitigation strategies which may recover performance more so than a simple rest break alone (Ross, Russell & Helton, 2014).

Attention Restoration Theory (ART), which proposes that interaction with nature may help restore cognitive resources which become depleted by tasks that require sustained attention , provides a useful framework for potentially combatting the phenomenon of vigilance decrement (Kaplan, 1995). ART hypothesizes that tasks which require humans to direct their attention for prolonged periods of time deplete our limited attentional capacity which may be replenished by interaction with nature because of we inherently fascinated by nature (which allows us to "effortlessly" attend to it) (Kaplan, 1995). Previous studies conducted within the field of Environmental Psychology have indicated both cognitive and affective benefits of interactions

with nature when compared to interaction with built or urban environments (Hartig, Mang & Evans, 1991). A major issue in the application of this body of literature however is that it is often a prerequisite that workers have access to natural environments which may not always be feasible. In fact, data from a U.S. census conducted in 2010 indicated that over 80% of the population in the United States lives in urban environments. Furthermore, submarine radar operators or power plant operators working in underground workplaces for example may find it difficult to take breaks in areas with an abundance of natural stimuli.

Advancements in display technology however now allow us to produce hyper-realistic and immersive images on displays which can be used to augment the work environment. Devices using these displays can be easily equipped by a variety of work environments to provide life-like scenes of nature indoors. An added benefit of these technologies over using plants in the workplace is that they require little to maintenance along with allowing the user to change the content as they please. The current study investigates the relative efficacy one can achieve in restoring performance by using 4k ultra-high definition televisions (UHDTV) along with head-mounted virtual reality devices (HMDs) to display restorative scenes of nature during a rest-break which occurs between two trials of a vigilance task. To this effect, participants in the current study were randomly assigned to one of 3 conditions. In the Virtual Reality (VR) condition, participants completed 2 trials of an abbreviated vigilance task with a rest break between each trial. During the break, participants viewed a 360 degree spherical video captured by a stereoscopic camera depicting a forest scene. In the television condition, participants viewed the same video during a break but on a 63” 4k UHDTV. In the control condition, participants did not view any video during the break. Participants were also administered a questionnaire assessing their stress state both before and after the vigilance trials along with a perceived workload measure post vigilance.

LITERATURE REVIEW

2.1 Background

Vigilance tasks require that individuals maintain focused attention on frequently occurring non-target stimuli for prolonged periods of time with the goal of detecting sporadically and infrequently occurring target stimuli (Warm, Parasuraman & Matthews, 2008). Human factors research on the topic of vigilance began during World War II when the British army became aware that radar operators, whose job was to detect enemy submarines & aircraft by use of radar technology, showed a marked decline in their ability to accurately detect enemy targets as a function of time spent on the job (Helton & Russel, 2011). Mackworth originally studied this decrease in the ability for people to maintain adequate vigilance performance over prolonged periods of time, known as vigilance decrement (1948). Using a mechanical clock in which participants monitored the clock's seconds hand for a sporadic "double jump", Mackworth found that people's ability to detect and react to this randomly occurring target event decreased by 10-15% within the first 30 minutes (Mackworth1948).

Since Mackworth's findings became published, a variety of other human factors researchers began investigating the topic as it provided an index for human performance as it related to automated and semi-automated systems (Warm & Parasurman, 2008). An important area of investigation into vigilance decrement became identifying various factors that may be related to vigilance performance. Previous studies have found that detection rates have been negatively effected by age (Parasurman & Giambra, 1991). Various studies have also indicated that environmental stressors which affect overall arousal may play an important role in vigilance decrement (See Ballard, 1996). For example, continuous high and low levels of background noise

have been found to be detrimental towards vigilance performance (Hancock, 1984; Broadbent, 1953). Furthermore, crowding, temperature and whole-body vibrations (such as which occurs in turbulence during flying) seem to also affect people's ability to detect critical signals on prolonged vigilance tasks (Hancock, 1984; Hancock & Warm, 1989: as cited in: Ballard, 1996). A review of 37 studies indicated that 50% of total vigilance decrement occurs within the first 15 minutes of participant's time on the task (Teichner, 1974). From this meta-analysis, Teichner (1974) was able to formulate a decrement function which helped to predict the phenomenon across various tasks difficulties.

While previous research has found that the vigilance decrement typically occurs around 15 minutes of watch, more recent work has found that, depending on task demands, vigilance decrement can occur within the first five minutes of beginning a task as defined by reduced accuracy and slower reaction times (Helton, Dember, Warm & Matthews, 2000, Teichner, 1974). Maintenance of vigilance is a critical component in a variety of jobs and tasks that includes but is not limited to semi-automated human-machine systems, military surveillance, boat navigation, quality control systems, and long-distance driving (Warm et. al, 2008). Therefore, properly identifying the potential cause of vigilance decrement and investing time in developing interventions that mitigates this decrease in performance is a useful endeavor with the end goal of reducing errors in critical situations. For example, in a flight-simulation study conducted by Molloy & Parasruman (1996), researchers found that simulated failures by the plane's automated monitoring system were less likely to be detected in the last 10-minutes of a 30-minute task than in the first 10 minutes of the task. Although conducted in a laboratory setting, the study points to the fact that failures to detect critical signals in life and death situations may result in catastrophic outcomes.

2.2 Theories of Vigilance Decrement

Mindlessness Theory

While a considerable amount of research has gone into documenting the phenomenon of vigilance decrement, researchers also became interested in figuring out why it occurs. Currently, there are two major theories that attempt to explain the occurrence of vigilance decrement. One of those theories, proposed by Manly, Robertson, Galloway, & Hawkins (1999) states that vigilance/sustained attention tasks promote a state of mindlessness in task performers. The mindlessness theory states that the low frequency of critical signals during prolonged and monotonous vigilance/sustained attention tasks decreases sensitivity (increases desensitization) to critical signals as a byproduct of decreased alertness (Dillard et. al, 2014; Warm et. al, 2008). That is, diminished arousal or withdrawal of attention caused by prolonged monotonous and repetitive tasks manifests in a decrease in accuracy and increase in reaction time by task performers in response to critical signals. This theory, which is based on the idea that a preferred level of arousal must be achieved by subjects in order to maintain adequate levels of performance has support in studies which indicate that depressants seem to diminish task performance while stimulants such as caffeine seem to enhance performance (Loebe & Alluisi, 1984). Furthermore, a study conducted by Ariga and Lleras (2011) found that task-switching during breaks resulted in significantly better performance on subsequent trials of an attention task when compared to a control group in which participants took no break.

Resource Theory

An alternative, and more recent theory, states that vigilance decrement occurs and increases as a function of the task's demand on limited-capacity attention and information processing systems (Grier et. al, 2003). In other words, the resource theory account for vigilance decrement states that a decrease in performance is a direct result of a fatigued attention system rather than a lack of arousal or the on setting of a state of mindlessness (Grier et. al, 2003). Unlike the mindlessness theory, the information processing/attentional load theory of vigilance decrement has a diverse and compelling body of literature in its support. Ranging from evidence in neuroimaging studies to subjective workload responses, evidence from a variety of disciplines seems to indicate that vigilance tasks place a high mental workload on the attentional systems of task performers (Grier et. al, 2008; Warm et. al, 2008;Helton & Russel, 2011; Dillard et. al, 2014). A recent study in which researches employed the use of noninvasive neuroimaging techniques such as transcranial Doppler sonography (TCD) and near infrared spectroscopy (NIRS) to monitor participants whilst they performed vigilance tasks found decreased blood flow velocities as a function of time on task in areas of the brain which are thought to correspond to attentional control (Warm, Matthews & Parasuraman, 2009). Neuroimaging studies are important in determining causes of vigilance decrement are that they provide insight into the neural activity which occurs during vigilance tasks, independent of performance metrics. That is, while various studies have shown there to be a link between the attentional fatigue hypothesis and vigilance decrement, these links are often only indexed by performance metrics which may have unknown underlying mechanisms.

While there are an extensive amount of studies investigating vigilance decrement and a large body of research that provides compelling support for the attentional model of vigilance

decrement, few studies within human factors have investigated potentially mitigating interventions. The following sections will discuss a potential theoretical framework known as attention restoration theory, embedded within the field of environmental psychology, by which mitigation of vigilance decrement may be achieved.

2.3 Restorative Effects of Natural Scenes.

Attention restoration theory (ART) argues that sustained attention (or vigilance) is a process by which inhibitory mechanisms cause one to direct attention to a particular task which eventually causes a gradual fatigue cognitive resources (Kaplan, 1995). Attention restoration theory as formulated by Kaplan & Kaplan (1989) also proposes that directed or focused attention may be restored by rest breaks that include engagement or interaction with nature. Specifically, ART hypothesizes that exposure to natural environments engages effortless attention processes that allow for directed attention processes to recover or "restore" (Kaplan & Kaplan, 1989). Multiple lab and field studies indicate that interactions with nature have cognitive benefits when compared to interactions with urban environments. For example, a multimethod study conducted by Hartig, Mang and Evans (1991) on wilderness and no wilderness vacationers along with a control condition indicated that participants who interacted with nature showed improved performance on a proofreading task and subjective states than control and non-wilderness vacation conditions. A multitude of studies have corroborated findings which suggest that access to nature has been linked to improved cognitive performance in comparison to groups where access to nature has been naturally and artificially limited (Kuo & Sullivan, 2001; Kuo & Taylor, 2004; Ottosson & Grahn, 2005; Tennessen & Cimprich, 1995 as cited in: Pilotti et. al, 2015).

Similar to the aforementioned theory of vigilance decrement that involves the limited-capacity attentional system, attention restoration theory states that effortful attention, requiring a cognitive control over attention, may fatigue executive functioning and lead to the decline in performance commonly seen in experimental tasks such as the sustained attention to response task (Berto, 2005). Since vigilance tasks require a great deal of directed attentional control, it can be deduced from the ART perspective that performance on vigilance/sustained attention tasks may be improved via the use of exposure to natural stimuli or environments. In fact a considerable amount of literature seems to indicate that rest breaks with either exposure to real natural environments or, exposure to simulated natural environments (i.e. images and videos), are efficacious in improving sustained attention performance on post-stimulus trials (Berto, 2005; Tennessen & Cimprich, 1995; Kaplan & Kaplan, 1989). For example, in a study conducted by Berto (2005), researchers found that a 5-minute rest break between two trials of the SART in which participants viewed pictures of 'restorative' natural scenes improved performance on the task in comparison to groups who viewed pictures of urban environments during the rest break. It is in this way that studies working within the framework of attention restoration theory may provide clues for ideating possible interventions that can be implemented in vigilance-heavy job settings to mitigate vigilance decrement.

One of the limitations of much of the research conducted within the ART framework is that it requires interaction and access to the natural environment. In many work environments such as submarines, radiology labs and office spaces located in dense urban environments, access to nature may be limited. What's more is that according to a recent Census report, over 80% of the population in the United States lives in "urbanized" areas. A common solution to this issue is

augmenting the workplace with indoor plants and art pieces however studies have shown little to no affective or performance benefits regarding their use (Evensen et. al, 2015; Larsen et. al, 1998). This effect may be due in part to the static nature of indoor plants and art pieces which workers may become quickly desensitized to. This perspective may be supported in part by Attention Restoration Theory which states than in order for something to be "restorative" it needs to evoke fascination or effortless attentional mechanisms which may only occur in the presence of more dynamic or changing stimuli. In addition to this, plants often require natural or artificial sunlight in order to survive along with proper maintenance. In workplaces such as power plant control centers where access to sunlight is limited, it may be difficult to maintain plant life without proper budgetary allocation to the care of them. Therefore, it is imperative that solutions to the issue of limited access to nature be addressed so that workers in high-stress environments can work as safely, efficiently and effectively as possible so as to prevent catastrophic errors from occurring.

2.4 Technological Interventions

Although augmenting workplaces with static indoor plants and art work has been found to be somewhat inefficacious as it relates to improvement of worker satisfaction and performance while access to real natural environments may be limited for many workers, advancements in technology may allow us to now bring hyper-realistic and immersive environments into the work place at relatively low financial and special costs. The benefit of using technological interventions as opposed to static art pieces or plants is that their output may be changed so that habituation or desensitization to the stimuli may become attenuated. What's more is that they may be easily fitted into variety of indoor environments and often require little to no maintenance (which can be cost

and time prohibitive). Because of this, technological interventions for combatting vigilance decrement may be worthwhile to explore.

One of the major advancements in the recent years has been improvements in display technologies. Over the past 10 years, mean pixels per inch of smart phones has increased by over 100% (Sayer, 2017). This advancement has also been paralleled by pixel density increases in televisions which allow for hyper-realistic images to be displayed on television sets. More recently, Ultra high-definition 4k displays have become popular which allow users to view realistic content at relatively low costs. Furthermore, large high-quality displays have been known to promote a sense of presence (Lin, Wu, Tang & Wu, 2013).

Increased pixel density, in conjunction with high-resolution film and photography also allow for the production of high-quality, realistic images to be made and displayed. Furthermore, these images can be viewed at closer and closer distances as pixels become less and less distinguishable from one another. One of most recent applications of this advancement in pixel density is the reemergence of virtual reality head mounted displays. Advancements in display technology has allowed for smartphone manufacturers to pack more and more pixels into already powerful and widely used hand-held devices. At the same time, companies have found that these same devices may be used as displays for relatively affordable head mounting gear in which these phones can be placed. It is in this way that popular smart-phone based headsets such as Google cardboard or Samsung VR-Gear came into the marketplace. Besides versatility and low costs associated with this technology, one of the added benefits of these smartphone based VR headsets is that they offer greater levels of immersion into virtual environments. This increased ability for users to be immersed into these environments may allow for an added sense of presence within the

environment. Therefore, it may be worthwhile investigating the application of these technologies in the workplace to restore worker performance.

2.5 Current Study

The current experiment expands on previous vigilance research conducted on the phenomenon of vigilance decrement by investigating previously unexplored mitigation strategies. While it is well known that rest recuperates performance on these tasks, few studies have investigated whether it may be possible to optimize rest periods via interaction with natural stimuli (Finkbeiner et. al, 2016; Plemmons, 2009; Ross, Russell & Helton, 2014). Working within the framework of Attention Restoration Theory (ART), the researchers attempt to mitigate the vigilance decrement by allowing for subjects to take breaks whilst interacting with technology mediated scenes of nature. In particular, we are interested in investigating whether or not certain mediums may be more or less efficacious in comparison to one another in restoring performance on a vigilance task. To this effect, the researchers employed the use of binocular and monocular 360 degree videos displaying a scene of nature in both virtual reality head sets and a 4k high definition television set respectively during rest breaks on an abbreviated vigilance task. Specifically the goal of the study was to determine if participants who took breaks while viewing a natural scene through virtual reality or through a HDTV would perform better on a vigilance task (as defined by faster reaction times and higher accuracy) when compared to a control group who took a standard rest break. From these goals, the following hypotheses were formulated:

Hypothesis 1: The conditions in which participants take a break using virtual reality and the television will have faster reaction times than control conditions (in which participants simply rest their eyes) on the post-break trials of the vigilance task.

Hypothesis 2: The conditions in which participants take a break using virtual reality and the television will have higher accuracy scores than control conditions on the post-break trials of the vigilance task.

Hypothesis 3: The conditions in which participants take a break using virtual reality and the television will report lower stress than control conditions after the post-break trial of the vigilance task.

Hypothesis 4: The conditions in which participants take a break using virtual reality and the television will report lower perceived workload than control conditions after the post-break trial of the vigilance task.

METHOD

3.1 Setting & Participants

45 university students (23% male, 77% Female) from Cornell University were recruited via convenience sampling for participation in the study. Participants were scheduled to participate in the Design, User Experience and Technology Lab (DUET) located within the Department of Design and Environmental Analysis at Cornell University. Participant's age ranged from 18-37 (*Mean age* = 22.45, *SD* = 4.97) and were randomly assigned to one of 3 groups [control, television or virtual reality (N = 15)]. All participants were either students or employees of the university and had normal or corrected-to-normal vision. Participants received either course credit or a $10 Amazon gift card for their participation in the study.

3.2 Procedure

To conduct the study a between groups experimental design was employed (see figure 2-3). Upon arriving, participants were asked to fill out a consent form informing them of the tasks they will be asked to complete and were randomly assigned to one of three condition (N = 15 per condition). They were also given information regarding any potential negative side effects regarding the use of virtual-reality head mounted displays (although there were minimal to no expected side effects). After completing the consent form, participants were asked to fill out a short demographics survey along few short questionnaires assessing their baseline stress state.

Participants were then seated in front of a 15" (diagonal) MacBook Pro laptop computer which was adjusted to match the participant's eye level. Participants sat at a distance of 50cm from

the screen with a brightness of 200 cd/m^2. A wired keyboard was also attached to the MacBook to allow for participants to easily reach the keyboard for the vigilance task. Upon being seated, participants were read instructions regarding the vigilance task they were to complete for the experiment and began a short practice trial (2 minutes) to help familiarize them with the task. Data from the practice session was discarded and not used for analysis. After the practice trial, any questions that the participants may have had regarding the task were answered by the researcher and participants were instructed to continue onto the first experimental trial which lasted 6 minutes. After completion of the first trial, participants were given a rest break which lasted 4 minutes and differed based on which condition the participants were randomly assigned to. The 4-minute rest break was chosen, in part, because of the limitations regarding the length of the video being shown. The 3 groups differed in the following ways:

1) **Control Condition**: Rest break in which no stimuli was to be viewed.
2) **Virtual Reality Condition**: Rest break in which participants viewed a 360 degree clip of a forest scene using a head-mounted display.
3) **Television Condition**: Rest break in which participants viewed a 360 degree clip of a forest scene on a 63” ultra-high definition television.

Figure 3-1: Virtual Reality Condition

Figure 3-2: Television Condition

Upon completion of the rest break, participants were again asked to complete a second trial of the vigilance task which lasted 6 minutes. Participants were then asked to complete a second stress state questionnaire along with a subjective workload measure.

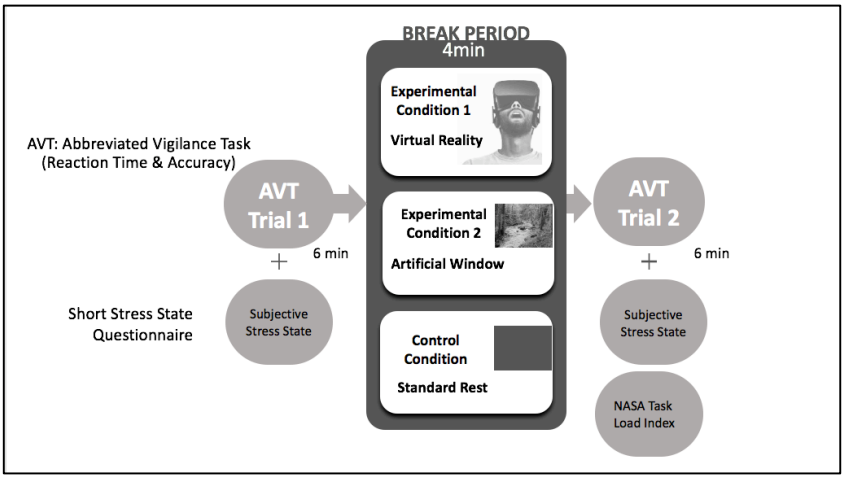

Figure 3-3: Experimental design

3.3 Abbreviated Vigilance Task

In order to measure vigilance performance in the current study, the abbreviated vigilance task (outlined by Temple et. al, 2000) was employed. The abbreviated vigilance task (AVT) is a short vigilance tasks, lasting roughly 12 minutes in its entirety and has been shown to produce similar decrements in accuracy as more prolonged vigilance tasks (Temple et. al, 2000). The AVT requires participants to maintain active watch of a screen with a white background on which 8 x 6 cm grey letters are briefly displayed for 50ms on a visual mask. The letters displayed are either the letter 'O', 'D' or a mirrored 'D' and are on display for 50ms (see figure 2-3). The interstimulus time was set at 1150 (similar to Finkbeiner et. al, 2016). The mask is comprised of small unfilled black circles with a diameter of 1mm. The circles on the mask were repeated and separated by 3mm in the horizontal direction and 3mm in the vertical direction (see figure 2-3). The contrast ratio between the white background and the capital letters was set to 45% as was outlined by Temple et. al (2000).

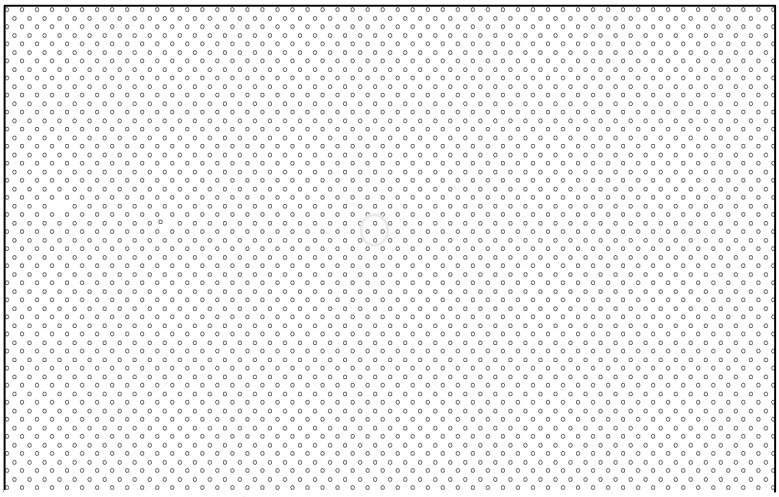

Figure 3-4: Target Stimuli

Participants were asked to respond to the presentation of the target letter (the letter 'O') by pressing the space bar as quickly as they could. No response was required for the nontarget letters. The letters were presented at a rate of 57.5 letters/min. Target letters were presented to participants with a probability of 0.2 while non-target letters were presented with a probability of 0.4 each. That is, only 20% of the letters presented to participants were the target stimuli. The first and second trial of the AVT lasted 6 minutes each. There was a 4-minute break between each trial. The 6-minute mark was chosen due to previous studies finding that most of the vigilance decrement in performance on the AVT occurs within the first 6 minutes of the task Finkbeiner et. al, 2016; Temple et. al, 2000). Therefore, to avoid fatigue effects of administrating two back-to-back vigilance tasks, the researchers decided to split the AVT into two 6 minute periods of watch.

3.4 Scales

Short Stress State Questionnaire (SSSQ)

The short stress state questionnaire developed by Helton (2004) is a 24-item multidimensional scale based on the Dundee Stress State Questionnaire (DSSQ; Matthews et al., 1999). Participants rate their agreement on a 5-point Likert scale (1 = not at all, 5 = extremely) to various items on the SSSQ. It is often used to assess participant's subjective stress state changes before and after a stressful task is completed (Helton and Russel, 2010). The dimensions measured by the stress state include Engagement, Worry and Distress which are addressed by 8 items on the scale. Of these, engagement and distress subscales are related to motivational and affective constructs regarding stress while the the distress subscale largely indexes cognitive aspects regarding stress (Helton & Naswall, 2010).

Previous studies have found that the SSSQ is a highly valid measure of subjective stress state and has been found to be related to participant performance on a variety of stress inducing tasks (Helton and Russel, 2010; Finkbeiner et.al, 2016). In the current study, the SSSQ was used to measure change in subjective stress state on the 3 dimensions as it relates to the differing conditions in the experiment. To this effect, the SSSQ was administered both prior to the first trial of the vigilance task and post trial 2 of the vigilance task to measure changes in stress state.

NASA Task Load Index (NASA-TLX)

The NASA task load index (TLX) is a 6-item questionnaire used to assess task-related mental workload (Hart & Staveland, 1988). Participants indicate their level of perceived workload on 6 dimensions (mental workload, physical workload, temporal workload, performance, effort and frustration) using a scale which ranges from 0-100. The NASA-TLX is a highly sensitive, widely used and validated measure of perceived workload (Hart, 2006). In the current study, the NASA-TLX was administered immediately after participants completed the second trial of the vigilance task.

3.5 Environmental Stimuli

The scene presented in the experimental conditions (television & virtual reality conditions) was chosen due to it being one of the only available stereoscopic high-definition videos available online depicting a natural environment. Furthermore, the video allows users to view in both

binocular views (for head mounted displays) and allows for mouse-control for monocular viewing. That is, in the virtual reality condition, participant's head position was tracked to allow for users to view parts of the scene they wanted to view. In the television condition, participants could use a mouse to direct the camera to the parts of the scene that they wanted to view. This allowed the participants to control the direction of the camera in the scene in both conditions so that they could view parts of the scene that most interested them.

The video was streamed on each device at their optimal resolution. A screen shot of the scene can be seen below in figure 2-4. The scene was captured by an independent film maker with a stereoscopic 360 degree camera. A stereoscopic video was chosen as this would allow for a deeper level of immersion for the virtual-reality condition (Yang, Schlieski, Selmins, Cooper, Doherty, Corriveau and Sheedy, 2012). The stereoscopic nature of the video, along with it depicting a scene of a forest was chosen for this study as previous studies have indicated that natural stimuli may be more beneficial for attention than other types of scenes (Laumann, Garling and Storkmark, 2003; Berto, 2005; Kaplan, 1995).

Figure 2-4: "Back to Nature 3-Rainforest" Video used in experiment: www.youtube.com/watch?v=GswgOe7ii8c&t=47s)

3.6 Display Devices

In the television condition, the scene of the forest was displayed on a 63" LG Ultra-High Definition LCD display. The television which has a resolution of 3840 x 2160 was placed 36" away from the seated participant's eye level. Participants could control the direction of the camera via use of a wireless optical mouse.

In the virtual reality condition, participants were instructed to view the same scene in a binocular head mounted display. The headset used in this experiment was the Samsung VR gear which is a smart-phone based virtual reality system. This headset a highly portable and cost-effective device which allows it to be used in a variety of locations and contexts where access to powerful CPU's is limited. The smart phone used in the experiment was the Samsung Galaxy S7 which as a resolution of 1440 x 2560. The smartphone's accelerometer allows the device to detect a user's head movement and gives users control over where they can look in an environment.

RESULTS

In order to analyze performance differences between groups, the abbreviated vigilance task, which lasted roughly 6 minutes per trial was divided into 6 separate periods of watch each lasting roughly 2 minutes each (total time of 12 minutes). The first 3 periods of watch occurred prior to the intervention or break period while periods 4-6 occurred post intervention. A One-way analysis of variance was conducted between each of the groups at each period of watch in order to detect differences between groups.

Baseline Reaction Time (ms)

A one-way between subjects ANOVA was conducted to compare differences in reaction time in the television, virtual reality and control conditions for each watch period prior to the break (baseline). No significant differences in reaction time were found between groups for watch periods 1 [$F(2, 40) = 0.3230$, $p = 0.7259$], 2 [$F(2, 40) = 0.111$, $p = 0.895$] and 3 [$F(2, 40) = 0.1038$, $p = 0.901$].

Post Intervention Reaction Time (ms)

A one-way between subjects ANOVA was conducted to compare differences in reaction time in the television, virtual reality and control conditions for each watch period after the break (post intervention). No significant differences in reaction time were found between groups for

watch periods 4 [F(2, 40) = 0.318, p = 0.7259], 5 [F(2, 40) = 1.4262, p = 0.2522] and 6 [F(2, 40) = 0.4509, p = 0.6402].

Table 4-1: ANOVA Summary Table (Reaction Times)

	df	SS	F	p
Period 1	2	0.0013	0.323	0.7259
Period 2	2	0.0006	0.111	0.8951
Period 3	2	0.0006	0.104	0.902
Period 4	2	0.0015	0.318	0.729
Period 5	2	0.0053	1.426	0.2522
Period 6	2	0.0022	0.451	0.6402

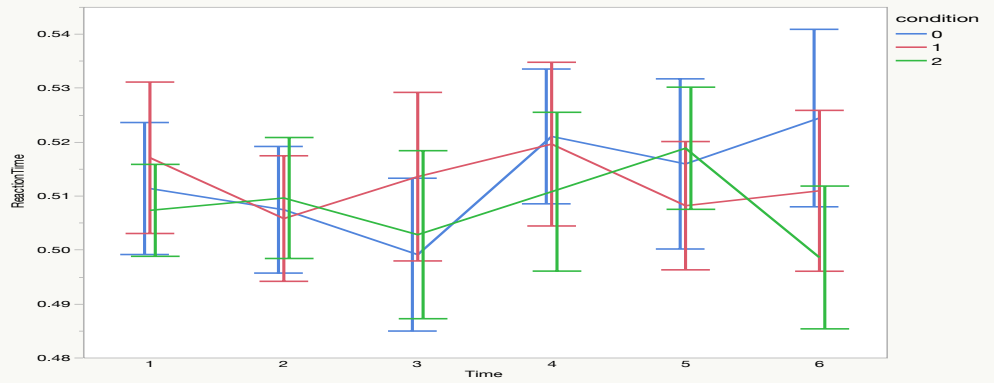

Figure 4-1 Reaction times over 6 periods of watch (0 = control, 1 = VR, 2 = TV).

Baseline Accuracy (%)

A one-way between subjects ANOVA was conducted to compare differences in accuracy in the television, virtual reality and control conditions for each watch period prior to the break (baseline). No significant differences in accuracy were found between groups for watch periods 1 [$F(2, 40) = 1.201$, $p = 0.311$], 2 [$F(2, 40) = 2.184$, $p = 0.126$] and 3 [$F(2, 40) = 0.518$, $p = 0.596$].

Post-Intervention Accuracy (%)

A one-way between subjects ANOVA was conducted to compare differences in accuracy in the television, virtual reality and control conditions for each watch period after the break (post intervention). There was a significant effect of break type on accuracy at the $p<.05$ level for the three conditions in watch period 1. Post hoc comparisons using the Tukey HSD test indicated that mean accuracy for the virtual reality conditions ($M = 0.98$, $SE = 0.008$) was significantly different than the television condition ($M = 0.9507$, $SE = 0.008$). However, the control condition did not significantly differ from the television and virtual reality conditions.

No significant differences in accuracy were found between groups for watch periods 5 [$F(2, 40) = 2.142$, $p = 0.1309$] and 6 [$F(2, 40) = 1.669$, $p = 0.201$].

Table 4-2: ANOVA Summary Table (Accuracy)

	df	SS	F	p
Period 1	2	0.0049	1.2019	0.311
Period 2	2	0.0097	2.1824	0.126
Period 3	2	0.0027	0.5182	0.6
Period 4	2	0.0081	3.7831	0.031
Period 5	2	0.01	2.14	0.131
Period 6	2	0.0093	1.6685	0.201

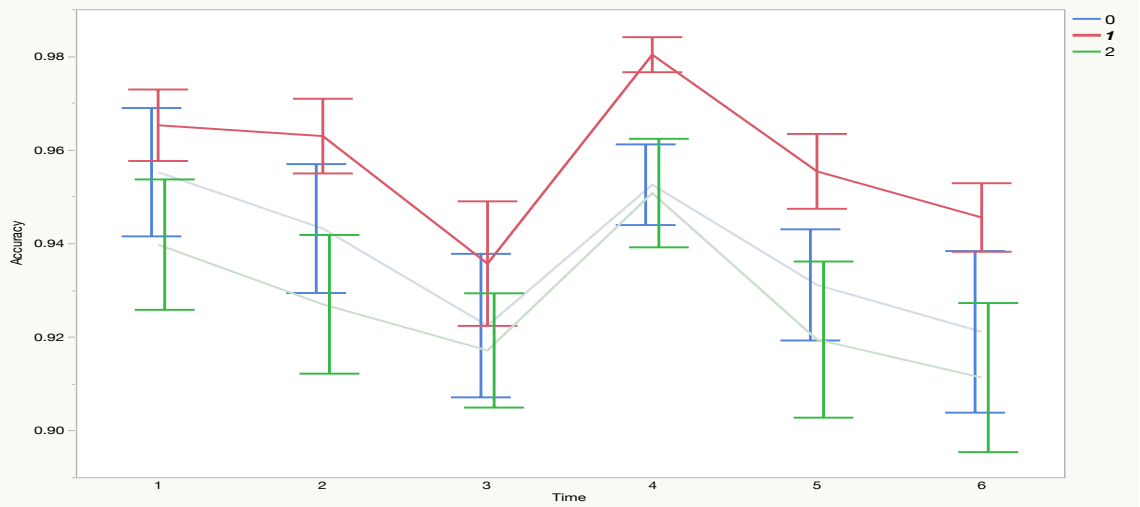

Figure 4-2: Accuracy over 6 periods of watch (0 = Control, 1 = VR, 3 = TV).

Subjective Stress (Short Stress State Questionnaire)

To calculate changes in subjective stress, participant scores on each of the sub dimensions (worry, distress & engagement) of the stress state questionnaire at baseline were subtracted from their scores on the second administration of the scale. These scores were then divided by the standard deviation of their responses on the first trial in order to compute a standardized z-score for a participant's change in subjective stress. The formula for computing this z-score is shown below.

Z-score of changes in stress state: $\frac{(SSSQ2 - SSSQ1)}{\sigma(SSQ1)}$

A one-way between subjects ANOVA was conducted for each subscale (distress, worry & engagement) to compare whether changes in stress state were significantly different in the television, virtual reality and control conditions. No significant differences in stress state change were found between groups for the subscales of distress [$F(2, 40) = 0.5125$, $p = 0.603$], worry [$F(2, 40) = 1.9724$, $p = 0.1531$] and engagement [$F(2, 40) = 2.483$, $p = 0.4763$].

Table 4-3: ANOVA Summary Table for change SSSQ subscales.

	df	SS	F	p
Distress	2	1.437288	0.5125	0.6031
Worry	2	5.844632	1.9724	0.1531
Engagement	2	2.482654	0.756	0.4763

Subjective Workload (NASA TLX)

A one-way between subjects ANOVA was conducted for to compare whether perceptions of subjective workload were significantly different in the television, virtual reality and control conditions. No significant differences in subjective workload were found between any of the 3 groups [$F(2, 40) = 0.0773$, $p = 0.925$].

DISCUSSION

The main goal of the current study was to investigate whether various technological interventions during rest periods between two vigils prove more efficacious in restoring performance than a standard rest break. A secondary goal was to investigate whether these various technological interventions would reduce perceived mental workload and reduce stress. Furthermore, working within the framework of Attention Restoration Theory (ART) which was used to guide selection of stimuli to be used during the breaks, the researcher was interested in seeing if providing subjects with a view of nature via virtual reality headset or television conditions would prove to be more restorative than a standard rest break.

While not all hypotheses were supported (hypothesis 1, 3 and 4) there were significant differences between the VR group and other conditions on the post-break vigil (support for hypothesis 2). That is, participants who were in the VR condition experienced restored accuracy performance on the AVT post break. This finding, while consistent with some studies (Beto, 2005; Hartig et. al, 1991) also seems to contradict others (Finkbeiner et. al, 2016). In that study, Finkbeiner and colleagues employed a similar paradigm in which participants were shown "natural" versus "built" stimuli during brief breaks in-between periods of watch on the AVT. However, the researchers used dog videos vs. robotic dog videos and had a no-break control condition. It may be that watching videos on a monitor may not be as strong of a manipulation as using a virtual reality headset. In fact, this finding seems to coincide with the current study in that accuracy performance in the television condition on the AVT was not significantly different than the control condition. This finding may also due, in part, to the fact that VR-headsets are often a novel stimuli for most people. From the perspective of ART, it may have been the

novelty of the VR-experience and not the content itself which may have caused participants to become fascinated. In order to control for this, future studies working within this paradigm will have to compare different types of content and measure performance and subjective states.

No significant differences between the three conditions were detected regarding scores on the NASA TLX. Although, participants in the VR condition, on average, did have slightly lower scores than control and TV conditions. This may be explained by the fact that the NASA TLX is often used as an index of perceived workload immediately following a particular task. Since all participants in the study performed the AVT, it may be that the NASA TLX is detecting perceived workload of the task and was not sensitive enough to detect effects from the various types of breaks. Another explanation of this finding may be that the manipulation only has short-lived effects that do not carry over extended periods of vigilance. This may be supported in part by the fact that there were no significant differences between groups for watch periods 4 and 5. Future studies employing the use of psychophysiological measurements may be more sensitive in detecting workload differences between groups.

Lastly, no significant differences were found between groups for changes in subjective stress on any of the subscales (distress, engagement or worry). While not significant, there was an overall increase in net feelings of distress, engagement and worry for the virtual reality conditions while there seemed to be a net *decrease* in these feelings for other conditions. This seems to be consistent with other studies which seem to implicate stress as a performance enhancing factor which may be mediated by interactions with nature (Pilotti et. al, 2015). Researchers in this study found that systolic blood pressure, a physiological indicator of stress, seemed to increase after watching a video of nature.

LIMITATIONS

Two major limitations of the current study is the relatively small sample size and relatively low difficulty of the vigilance task. The study only employed the use of 45 participants (15 participants in each condition) which may have limited the statistical power to find significant differences between groups for the subjective measures. In addition to this, since all participants were college students or employees of the university, future iterations of this study may benefit from the use of a more diverse population or use of lab technicians and employees within various industries who perform this type of task on a daily basis.

Furthermore, participants performed relatively well on the task which may indicate that version of the AVT used in this experiment may have been too easy. In addition to this, participants only decreased in their performance in the first 6 minutes by 4-6%. In other studies using this task, participa nt's accuracy performance decreased by roughly 10% in the first 6 minutes (Temple et. al, 2000). This may have been due to a variety of factors such as room lighting which was the same for all participants but not measured. The relatively dim lighting in the laboratory may have increased participant's contrast sensitivity, making the task somewhat easier. Other limitations in the study include gender imbalances, the recruitment of participants who were primarily younger in age. Finally, as discussed earlier a comparison VR group is needed to validate whether or not the content of the VR condition was effective or if it was the overall novelty of using the device.

REFERENCES

Ariga, A., & Lleras, A. (2011). Brief and rare mental "breaks" keep you focused: Deactivation and reactivation of task goals preempt vigilance decrements. Cognition, 439-443.

Ballard, J. C. (1996). Computerized assessment of sustained attention: A review of factors affecting vigilance performance. Journal of Clinical and Experimental Neuropsychology, 18(6), 843–863. http://doi.org/10.1080/01688639608408307

Berto, R. (2005). Exposure to restorative environments helps restore attentional capacity. Journal of Environmental Psychology, 25(3), 249–259. http://doi.org/10.1016/j.jenvp.2005.07.001

Bowden, E.M., & Jung-Beeman, M. (2003). Normative data for 144 compound remote associate problems Behavioral Research Methods, Instrumentation, and Computers, 35, 634-639.

Broadbent, D.E. (1954). Some effects of noise on visual performance. Quarterly Journal of Experimental Psychology, 6, 1-5.

Dillard, M. B., Warm, J. S., Funke, G. J., Funke, M. E., Finomore, V. S., Matthews, G., … Parasuraman, R. (2014). The Sustained Attention to Response Task (SART) Does Not Promote Mindlessness During Vigilance Performance. Human Factors, 56(8), 1364–1379. http://doi.org/10.1177/0018720814537521

Evensen, K. H., Raanaas, R. K., Hagerhall, C. M., Johansson, M., & Patil, G. G. (2015). Restorative Elements at the Computer Workstation. Environment and Behavior, 47(3), 288–303. http://doi.org/10.1177/0013916513499584

Finkbeiner, K. M., Russell, P. N., & Helton, W. S. (2016). Rest improves performance, nature improves happiness: Assessment of break periods on the abbreviated vigilance task. *Consciousness and Cognition*, *42*, 277–285. http://doi.org/10.1016/j.concog.2016.04.005

Grier, R. A., Warm, J. S., Dember, W. N., Matthews, G., Galinsky, T. L., Szalma,J.L., et al. (2003). The vigilance decrement reflects limitations in effortful attention, not mindlessness. Human Factors, 45, 349–359.

Guilford, J.P. (1967). The nature of human intelligence. New York, NY: McGraw-Hill.

Hancock, P.A. (1984). Environmental stressors. In J.S. Warm (Ed.), Sustained attention in human performance (pp. 103-142). Chichester: John Wiley & Sons.

Hart, S. G. (2006). NASA-TASK LOAD INDEX (NASA-TLX); 20 YEARS LATER. Full-Text, 904–908.

Hartig, T., Mang, M., & Evans, G. W. (1991). Restorative Effects of Natural Environment Experiences. Environment and Behavior. http://doi.org/10.1177/0013916591231001

Helton, W. S., Dember, W. N., Warm, J. S., & Matthews, G. (2000). Optimism, pessimism, and false failure feedback: Effects on vigilance performance. Current Psychology: Developmental, Learning, Personality, Social, 18(4), 311–325. http://doi.org/10.1007/s12144-999-1006-2

Helton, W. S., & Russell, P. N. (2010). The Short Stress State Questionnaire and High Event Rate Target Detection Christchurch , New Zealand.

Helton, W. S., & Nöswall, K. (2010). Short stress state questionnaire: Factor structure and state change assessment. *European Journal of Psychological Assessment*, *31*(1), 20–30. http://doi.org/10.1027/1015-5759/a000200

Kaplan, R. (2001). The Nature of the View from Home: Psychological Benefits. *Environment and Behavior*, *33*(4), 507–542. http://doi.org/10.1177/0013916012197311

Larsen, L., Adams, J., Deal, B., Kweon, B. S., & Tyler, E. (1998). Plants in the workplace: The effects of plant density on productivity, attitudes, and perceptions. Environment and Behavior, 30, 261-281.

Laumann, K., Gärling, T., & Stormark, K. M. (2003). Selective attention and heart rate responses to natural and urban environments. *Journal of Environmental Psychology*, *23*(2), 125–134. http://doi.org/10.1016/S0272-4944(02)00110-X

Laugwitz, B., Schrepp, M. & Held, T. (2008). Construction and evaluation of a user experience questionnaire. In: Holzinger, A. (Ed.): USAB 2008, LNCS 5298, 63-76.

Lin, T., Wu, Z., Tang, N., & Wu, S. (2013). Exploring the effects of display characteristics on presence and emotional responses of game players. International Journal of Technology and Human Interaction, 9(1), 50+. Retrieved from http://go.galegroup.com.proxy.library.cornell.edu/ps/i.do?p=AONE&sw=w&u=nysl_sc_cornl&v=2.1&it=r&id=GAL%7CA339919214&sid=summon&asid=4cc24bba9413f9bf7c0598187c7ef6cf

Loeb, M., & Alluisi, E. A. (1984). Theories of vigilance. In J. S. Warm (Ed.), Sustained attention in human performance (pp. 179–205). Chichester, UK: Wiley.

Parasuraman, R., & Giambra, L. (1991). Skill development in vigilance: Effects of event rate and age. Psychology and Aging, 6, 155.169.

Pilotti, M., Klein, E., Golem, D., Piepenbrink, E., & Kaplan, K. (2015). Is Viewing a Nature Video After Work Restorative? Effects on Blood Pressure, Task Performance, and Long-Term Memory. *Environment and Behavior*, *47*(9), 947–969. http://doi.org/10.1177/0013916514533187

Robertson, H., Manly, T., Andrade, J., Baddeley, B. T., & Yiend, J. (1997). 'Oops!': Performance correlates of everyday attentional failures in traumatic brain injured and normal subjects. Neuropsychologia, 35(6), 747-758

Studente, S., Seppala, N., & Sadowska, N. (2016). Facilitating creative thinking in the classroom: Investigating the effects of plants and the colour green on visual and verbal creativity. Thinking Skills and Creativity, 19, 1–8. http://doi.org/10.1016/j.tsc.2015.09.001

Teichner, W. H. (1972). The detection of a simple visual signal as a function of time on watch. *Human Factors*, *16*(4), 339–353. http://doi.org/10.1177/001872087401600402

Temple, J. G., Warm, J. S., Dember, W. N., Jones, K. S., LaGrange, C. M., & Matthews, G. (2000). The Effects of Signal Salience and Caffeine on Performance, Workload, and Stress in an Abbreviated Vigilance Task. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *42*(2), 183–194. http://doi.org/10.1518/001872000779656480

Tennessen, C. M., & Cimprich, B. (1995). Views to nature: Effects on attention. Journal of Environmental Psychology, 15(1), 77–85. http://doi.org/10.1016/0272-4944(95)90016-0

Warm, J. S., Matthews, G., & Parasuraman, R. (2009). Cerebral hemodynamics and vigilance performance. *Military Psychology*, *21*(Suppl 1), S75–S100. http://doi.org/10.1080/08995600802554706

Warm, J. S., & Parasuraman, R. (2008). Vigilance Requires Hard Mental Work and Is Stressful, 50(3), 433–441. http://doi.org/10.1518/001872008X312152.

Yang, S., Schlieski, T., Selmins, B., Cooper, S. C., Doherty, R. A., Corriveau, P. J., & Sheedy, J. E. (2012). Stereoscopic Viewing and Reported Perceived Immersion and Symptoms. *Optometry and Vision Science*, *89*(7), 1068–1080. http://doi.org/10.1097/OPX.0b013e31825da430